MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

DET5038 – POWER ELECTRONICS

(Diploma in Electronics Engineering)

24 OCTOBER 2017
9:00 a.m – 11:00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of **9** pages (**7** pages with **5** questions and **2** pages for appendix).

2. Answer ALL questions. All necessary working steps must be shown.

3. Write all your answers in the answer booklet provided.

QUESTION 1 [20 marks]

(a) Sketch the I-V characteristic of a N-Channel Power MOSFET. Label the Ohmic region, Active region and Cutoff region in your diagram. Then, briefly explain the parameter of BV_{DSS}, I_{DSS}, $V_{GS(TH)}$ and $R_{DS(ON)}$.

(10 marks)

(b) Briefly explain the operation of a Single Phase Half Wave Rectifier with a pure resistive load based on Figure 1. Draw the input Vs(t) and output $V_R(t)$ waveform.

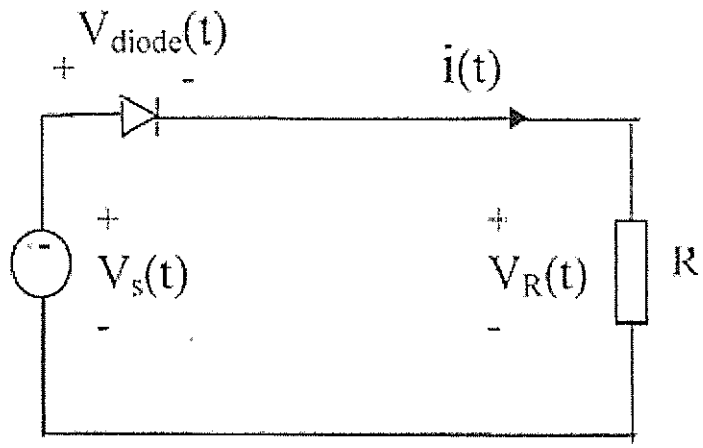


Figure 1

(10 marks)

Continued ...

QUESTION 2 [20 marks]

(a) Draw the schematic diagram of a Buck DC-DC Converter, a Boost DC-DC Converter and a Buck-Boost DC-DC Converter. State the main function for each types of the converters.

(10 marks)

(b) Explain the function of a Pulse Width Modulator (PWM).

(6 marks)

(c) Figure 2 shows the circuit diagram of a simple series resonant inverter with unidirectional switches. Provide TWO limitations compensated by this inverter.

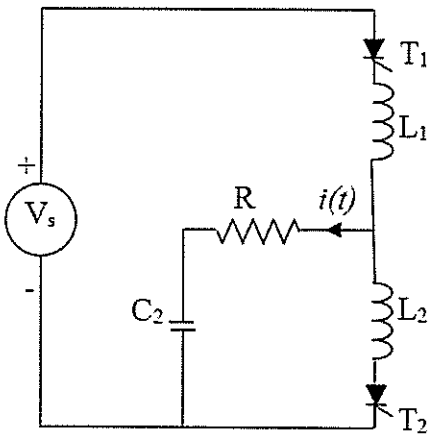


Figure 2

(4 marks)

Continued ...

QUESTION 3 [20 marks]

Based on Figure 3, a power MOSFET is used as a switch to energize a resistive load. Assume that the transistor ON state time is twice of the OFF state time at a switching frequency of 500 kHz.

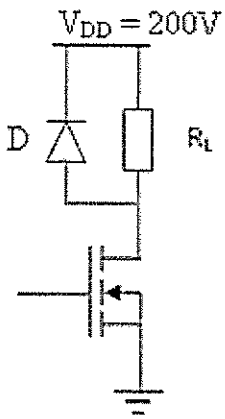


Figure 3

By using the following data below, find the total power loss incurred by the MOSFET.

$V_{GS} = 10V$
$V_{GS(TH)} = 5V$
$I_{DSS} = 100uA$
$R_{DS(on)} = 0.02\Omega$
$I_{D(on)} = 10A$
$\tau_{on} = 10ns$
$\tau_{off} = 100ns$

(20 marks)

Continued ...

QUESTION 4 [20 marks]

(a) Figure 4 shows a rectifier circuit with the input voltage waveform. The rectifier circuit is required to produce an average output voltage, $V_{o,avg}$ of 63 V. Determine the following:

(i) Average current flowing in the circuit.

(2 marks)

(ii) Value of the extinction angle, β.

(4 marks)

(iii) RMS value of output voltage.

(4 marks)

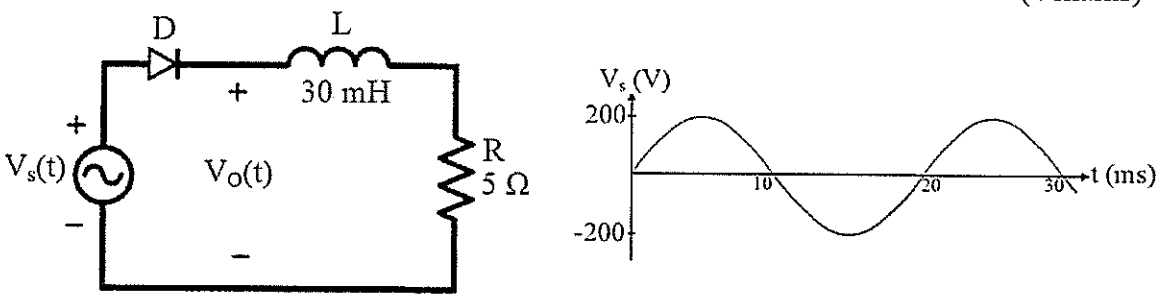


Figure 4

Given formula:

$$V_{o,avg} = \frac{\sqrt{2}V_{s,rms}}{2\pi}[1-\cos(\beta)]$$

$$V_{o,rms} = \frac{V_{S,rms}}{\sqrt{2\pi}}\sqrt{\beta - \frac{\sin 2\beta}{2}}$$

Continued ...

(b) A boost converter is operating from 10 V DC voltage source. It supplies 60 W across a 8 Ω load resistor under continuous conduction mode at the frequency of 25 Hz. Assume that the filter capacitance is very large and neglect the ON state voltage drop across the diode. Determine for the following:

(i) The output voltage and duty ratio.

(4 marks)

(ii) The minimum inductance value needed for this converter.

(3 marks)

(iii) The output ripples voltage produced by 20mF capacitor.

(3 marks)

Continued ...

QUESTION 5 [20 marks]

(a) A single-phase half-bridge inverter has a dc input voltage of $V_s = 300 \ V$. Determine:

(i) The RMS output voltage of the fundamental component.

(1 mark)

(ii) The RMS output voltage.

(1 mark)

(iii) The RMS output voltage of total harmonic component.

(2 marks)

(iv) The harmonic factor of the 1st, 2nd and 3rd harmonic.

(2 marks)

(v) The total harmonic distortion.

(2 marks)

(vi) The voltage transfer ratio.

(2 marks)

Continued ...

(b) A series resonant converter is operating at an output frequency of 8 kHz. The circuit turn off time is given as 45 μs.

(i) Sketch the circuit diagram of a series resonant converter. Label all the components clearly.

(5 marks)

(ii) Assume that the circuit turn off time is five times longer than the thyristor turn off time, determine the maximum permissible frequency, f_{max} .

Hint: $f_{\max} = \dfrac{1}{2(t_q + \dfrac{\pi}{\omega_r})}$

(5 marks)

End of Page.

APPENDIX

Table 1 Switching power loss of power BJT

	Resistive Load	Inductive Load
ON state	$P_{on} = [V_{CE(sat)} I_{C(on)} + V_{BE(on)} I_{B(on)}] \frac{t_{on}}{T}$	$P_{on} = [V_{CE(sat)} I_{C(on)} + V_{BE(on)} I_{B(on)}] \frac{t_{on}}{T}$
OFF state	$P_{off} = [V_{CC} I_{C(leak)}] \frac{t_{off}}{T}$	$P_{off} = [V_{CC} I_{C(leak)}] \frac{t_{off}}{T}$
Turn On	$P_{turn-on} = V_{CC} I_{C(on)} \frac{\tau_{on}}{6T}$	$P_{turn-on} = V_{CC} I_{C(on)} \frac{\tau_{on}}{2T}$
Turn Off	$P_{turn-off} = V_{CC} I_{C(on)} \frac{\tau_{off}}{6T}$	$P_{turn-off} = V_{CC} I_{C(on)} \frac{\tau_{off}}{2T}$

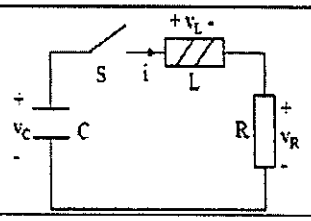
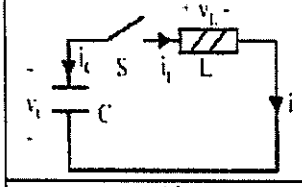
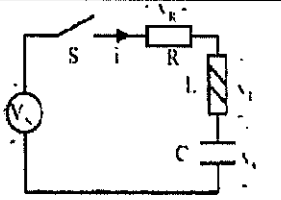
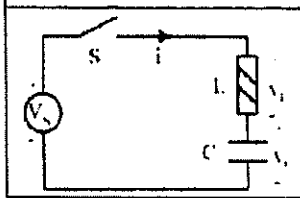
Table 2 Switching power loss of power MOSFET

	Resistive Load	Inductive Load
ON state	$P_{on} = I_{D(on)}^2 R_{DS(on)} \frac{t_{on}}{T}$	$P_{on} = I_{D(on)}^2 R_{DS(on)} \frac{t_{on}}{T}$
OFF state	$P_{off} = I_{D(off)} V_{DD} \frac{t_{off}}{T}$	$P_{off} = I_{D(off)} V_{DD} \frac{t_{off}}{T}$
Turn On	$P_{turn-on} = \frac{V_{DD} I_{D(on)} \tau_{on}}{6T}$	$P_{turn-on} = \frac{V_{DD} I_{D(on)} \tau_{on}}{2T}$
Turn Off	$P_{turn-off} = \frac{V_{DD} I_{D(on)} \tau_{off}}{6T}$	$P_{turn-off} = \frac{V_{DD} I_{D(on)} \tau_{off}}{2T}$

Table 3 Useful equations of DC to DC converters

Buck Converter	Boost Converter	Buck-Boost Converter
$V_o = DV_s$	$D = 1 - \frac{V_s}{V_o}$	$D = \frac{V_O}{V_s + V_O}$
$I_L = \frac{V_o}{R}$ $(\Delta i_L)_{close} = \frac{V_s - V_o}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$	$I_L = \frac{V_s}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_s}{L} DT$ $(\Delta i_L)_{open} = \frac{V_S - V_o}{L}(1-D)T$	$I_L = \frac{V_s D}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_S}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$
$L = \frac{(1-D)R}{2f}$	$L = \frac{D(1-D)^2 R}{2f}$	$L = \frac{(1-D)^2 R}{2f}$
$C_{min} = \frac{1-D}{8Lf^2 \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$

Table 4 Current (i) and capacitor voltage (V_c) expressions for resonant circuits.

	$i = \frac{V_0}{\omega_r L} e^{-\alpha t} \sin \omega_r t$ $V_c = V_0 e^{-\alpha t}\left[(\alpha/\omega_r)\sin(\omega_r t) + \cos(\omega_r t)\right]$
	$i = \frac{V_0}{\omega_o L} \sin \omega_o t$ $V_c = V_0 \cos \omega_o t$
	$i = \frac{V_s - V_0}{L\omega_r} e^{-\alpha t} \sin \omega_r t$ $V_C = -(V_S + V_0)e^{-\alpha t}\left[\frac{\alpha}{\omega_r}\sin \omega_r t + \cos \omega_r t\right] - V_0$
	$i = \frac{V_S - V_O}{Z_O} \sin \omega_O t$ $V_C = V_S - (V_S - V_O)\cos \omega_O t$